

SEE Test Report V1.0  
 Heavy ion SEE test of ATF22V10B-10GM/883 from ATMEL  
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## I. Introduction

This study was undertaken to determine the single event destructive and single event upset (SEU) susceptibility of the electrically erasable programmable logic device (EEPLD) ATF22V10B from ATMEL. The device was monitored for SEU and for destructive events induced by exposing it to a heavy ion beam at Texas A&M Cyclotron Single Event Effects Test Facility. This test was performed in the frame of HST project.

## II. Devices Tested

The sample size of the testing is four devices. The test samples lot date code is 0437. Device package marking is as follows:

ATMEL C 0C0437 A  
 5962-8984106LA  
 ATF22V10B-10GM/883

The device technology is CMOS flash. The device is packaged in a 24-pin ceramic DIP package. Test samples were prepared for test by delidding.

For these tests the test samples were programmed as 10 flip-flop shift registers with asynchronous set and reset inputs. Set input is active at high logic level. Reset input is active at low logic level.

## III. Test Facility

**Facility:** TAMU Cyclotron Single Event Effects Test Facility

**Flux:**  $1 \times 10^3$  to  $1 \times 10^5$  particles/cm<sup>2</sup>/s.

**Fluence:** For destructive events, all tests were run to  $1 \times 10^7$  p/cm<sup>2</sup> or until destructive events occurred

For non destructive events, all tests were run to  $1 \times 10^6$  p/cm<sup>2</sup> or until a sufficient (>100) number of transient events occurred.

The ions and LET values used for these tests are shown in Table 1.

Table 1: Ions used for the test

<b>Ion</b>	<b>Energy at target (MeV)</b>	<b>LET at target (MeVcm<sup>2</sup>/mg)</b>
Ne	270	2.8
Ar	508	7.8
Kr	953	28.8
Xe	1336	53.1

#### IV. Test Conditions and Error Modes

**Test Temperature:**

Room Temperature

**Bias conditions**

Vcc = 5.5V for SEL, 4.5V for SEU

Clock frequency: 1, 10, and 25 MHz

DUT pinout is shown in Figure 1.

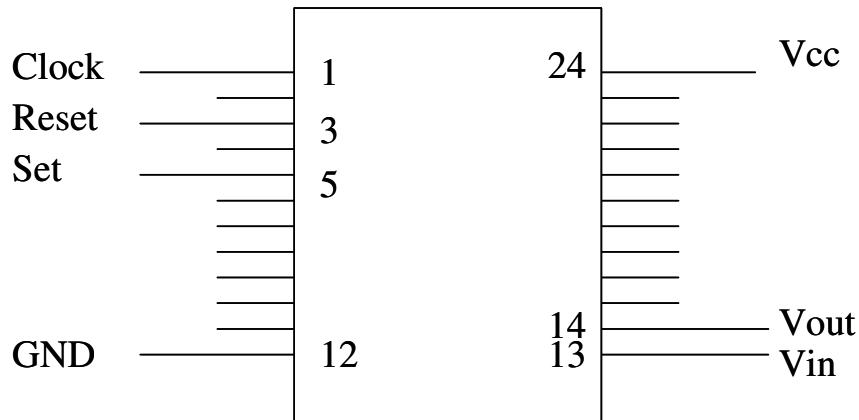


Figure 1: DUT pinout

**PARAMETERS OF INTEREST:** Power supply currents, shift register output

**SEE Conditions:** SEL, SEGR, SEU, SET

#### V. Test Methods

ATF22V10 was tested with NASA-GSFC REAG (Radiation Effects and Analysis Group) Low Cost Digital Tester (LCDT). LCDT is a reusable universal digital device tester based on Xilinx Spartan 3 Field Programmable Gate Array (FPGA) with input/output (I/O) operation speed up to 200 MHz.

LCDT is the main test board that interfaces with the Device under test (DUT) specific daughter card. The DUT on the daughter card is exercised using the configurable FPGA on LCDT with Hardware Design Language such as VHDL based coding. A remote PC controls LCDT.

During irradiation, DUT power supply current was monitored. Nominal current at 1 MHz is 95 mA. As soon as power supply current reaches a programmable SEL detection level of 150 mA, DUT power supply is shutdown.

Before each irradiation run, a test pattern was entered in the shift register input. Set and reset inputs were inactive during the tests. The shift register output was compared to the test pattern. Errors were counted and error information was stored. Three different test patterns were investigated: all0, all1, and alternate (checkerboard).

## VI. Test Results

Test log is shown in Appendix. Three out of the four tested parts failed during the tests. Failures were not related to SEL events as DUT power supply current did not increase. Failed parts stopped working and it was not possible to recover functionality even after a power cycle. Failure appeared at high LET (53, 57 and 106 MeVcm<sup>2</sup>/mg) and event cross-section is small ( $\sim 1E-7$  cm<sup>2</sup>/dev). One week after the test we tried to reprogram the three failed parts (SN2, SN2, and SN4). Part SN3 recovered functionality, but the other two (SN2 and SN4) failed reprogramming.

We observed SEU and burst errors during the tests. Figure 2 shows the SEU cross-sections for the different test conditions investigated.

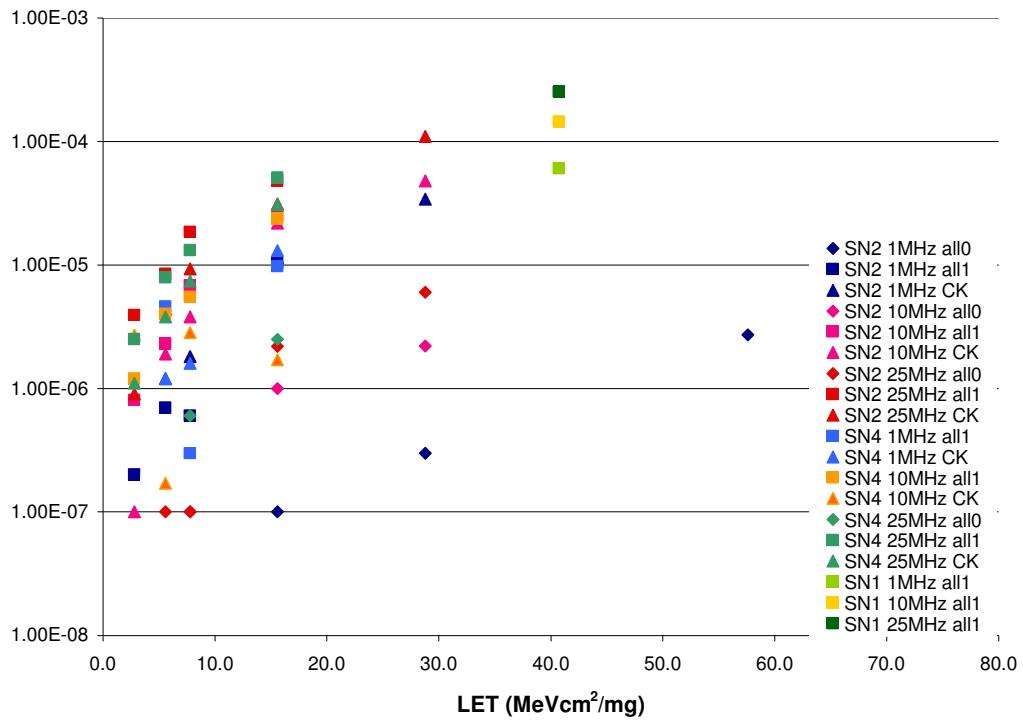


Figure 2: SEU cross-sections

Figure 3 shows measured cross-section for the worst case test pattern (all 1). We can see a significant effect of frequency. Measured cross-sections increase with clock frequency. This means that SETs contribute significantly to the flip-flop errors.

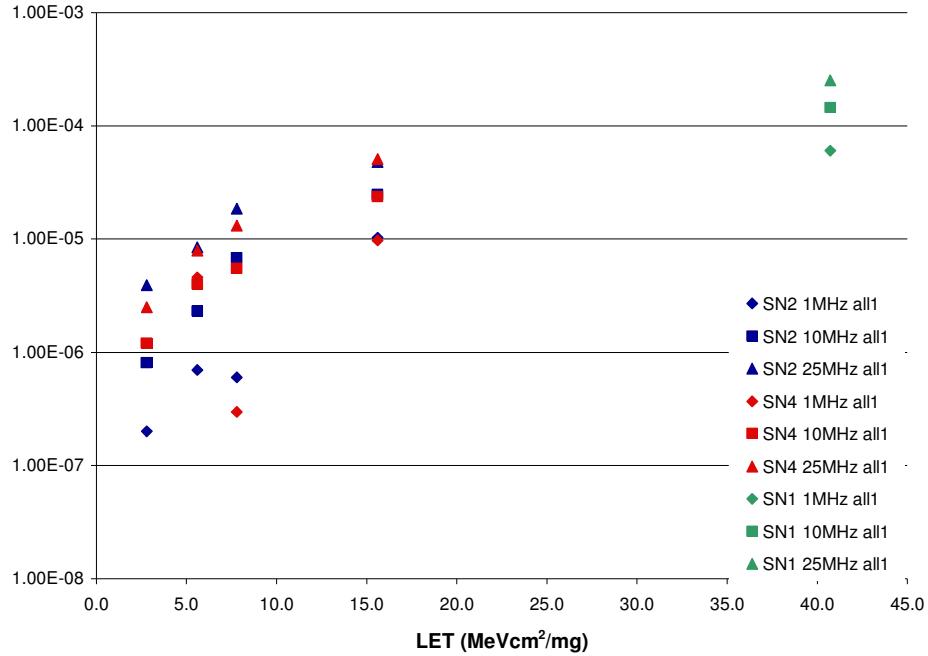


Figure 3: SEU cross-sections, effect of clock frequency

Figure 4 shows the effect of test pattern on measured SEU cross-sections. We can see a significant effect of test pattern. Flip-flops are more sensitive to 1-to-0 transitions than 0-to-1 transitions.

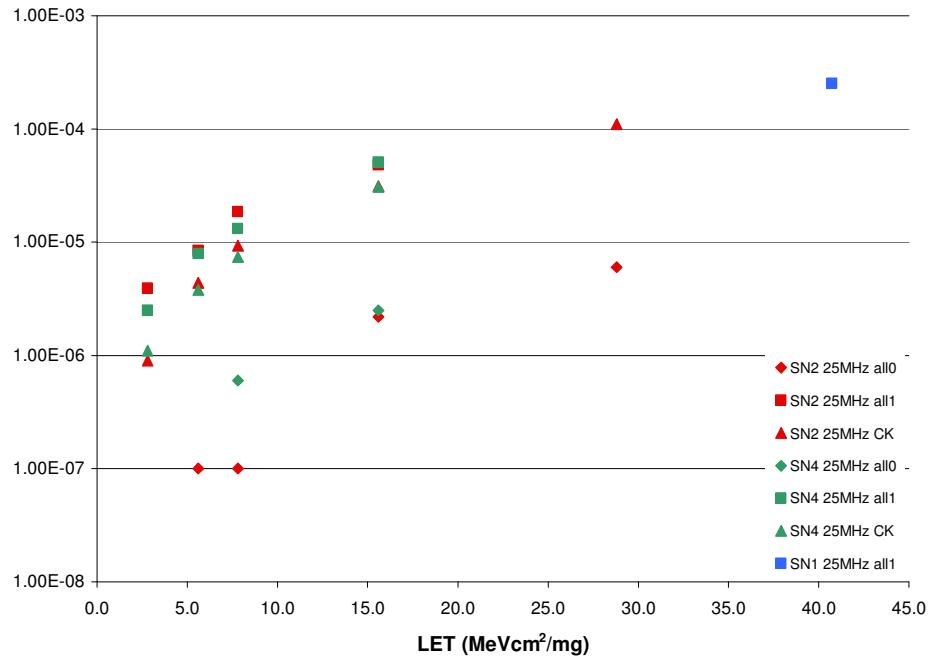


Figure 4: SEU cross-sections, effect of test pattern

Figure 5 shows burst error cross-sections. Bursts are caused by SET in device set or reset inputs. Therefore we can have up to 10 flip-flops in error. Figure 6 shows an example of burst errors. DUT was irradiated will an all 0 pattern. We observed 11 isolated errors (0 to 1 transitions), then a burst of 9 successive 0 to 1 transitions. This means that a transient occurred to the set signal and reached 9 out of the 10 flip-flops in the device. With an all 0 pattern, SET occurring on flip-flops reset input can't be seen. We can see in Figure 5 a strong effect of test pattern on burst sensitivity. We observed more bursts with all1 pattern. Reset signal looks more sensitive to SETs than Set signal. We don't know if it is due to flip-flop design itself or to the fact that we define Reset signal active at low level and Set signal active at high level.

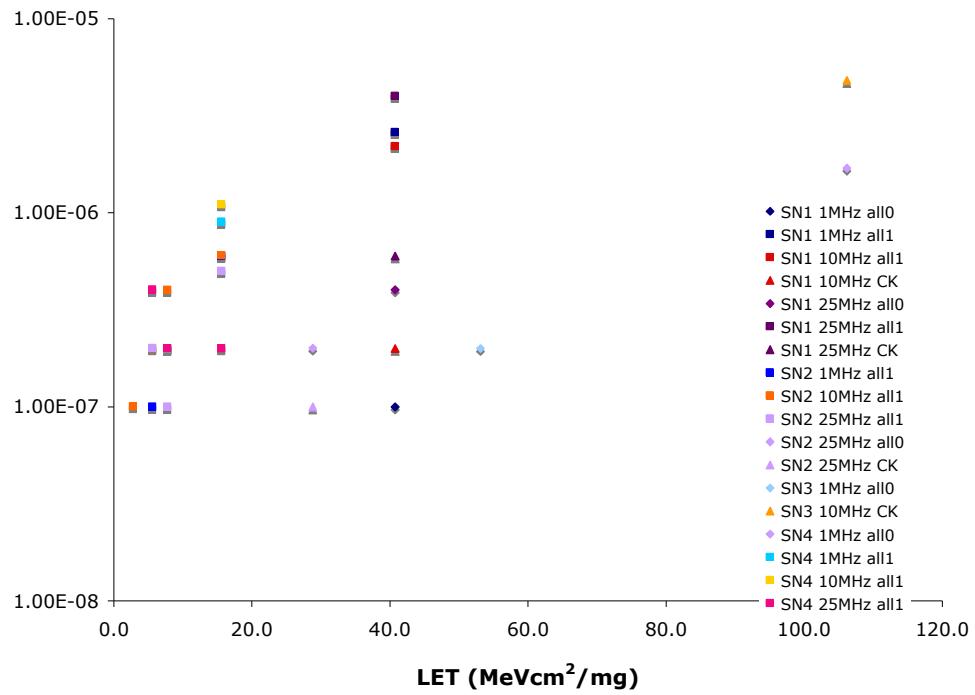


Figure 5: burst error cross-section

TIME	ErrorCnt	Burst	Pattern	Transition
672758	1	0	0	0->1
674410	2	0	0	0->1
686149	3	0	0	0->1
701517	4	0	0	0->1
733766	5	0	0	0->1
749661	6	0	0	0->1
751542	7	0	0	0->1
758488	8	0	0	0->1
766802	9	0	0	0->1
769569	10	0	0	0->1
771634	11	0	0	0->1
829854	12	0	0	0->1
<b>829854</b>	<b>13</b>	<b>1</b>	<b>0</b>	<b>0-&gt;1</b>
<b>829854</b>	<b>14</b>	<b>2</b>	<b>0</b>	<b>0-&gt;1</b>
<b>829854</b>	<b>15</b>	<b>3</b>	<b>0</b>	<b>0-&gt;1</b>
<b>829854</b>	<b>16</b>	<b>4</b>	<b>0</b>	<b>0-&gt;1</b>
<b>829854</b>	<b>17</b>	<b>5</b>	<b>0</b>	<b>0-&gt;1</b>
<b>829854</b>	<b>18</b>	<b>6</b>	<b>0</b>	<b>0-&gt;1</b>
<b>829854</b>	<b>19</b>	<b>7</b>	<b>0</b>	<b>0-&gt;1</b>
<b>829854</b>	<b>20</b>	<b>8</b>	<b>0</b>	<b>0-&gt;1</b>
864394	21	0	0	0->1
896739	22	0	0	0->1
922596	23	0	0	0->1

Errs=23 Burst Occurrences=1 Adj Err Cnt=14

Figure 5: example of data file with burst errors

## VII. Conclusions

Atmel PAL ATF22V10 is sensitive to heavy ion induced destructive events at high LET ( $> 53 \text{ MeVcm}^2/\text{mg}$ ). Destructive event cross-section is low ( $\sim 1\text{E}-7 \text{ cm}^2/\text{dev}$ ). Therefore, the risk of failure on HST will be low.

ATF22V10 flip-flops are sensitive to heavy ion induced SEUs with a maximum measured cross-section of  $\sim 5\text{E}-5 \text{ cm}^2/\text{flip-flop}$  and a LET threshold lower than  $2.8 \text{ MeVcm}^2/\text{mg}$ . Because of low SEU LET, ATF22V10 may also be sensitive to proton induced SEUs. Test results also show a pattern dependence and a sensitivity to SETs. SET sensitivity may cause burst errors when they happen on Set and Reset signals.

## Appendix

Run #	DUT #	CK Speed (MHz)	Pattern	angle	effective LET (MeVcm <sup>2</sup> /mg)	Total error #	SEU #	Burst #	Dest #	Fluence (#/cm <sup>2</sup> )	Xsec SEU (cm <sup>2</sup> /dev)	Xsec burst (cm <sup>2</sup> /dev)	sigma dest (cm <sup>2</sup> /dev)	
162	4	1	1	0	7.8	23	3	2	0	1.0E+07	2.97E-07	1.98E-07	0.00E+00	
163	4	1	ckbd	0	7.8	16	16	0	0	1.00E+07	1.60E-06	0.00E+00	0.00E+00	
164	4	10	0	0	7.8	1	1	0	0	1.00E+07	1.00E-07	0.00E+00	0.00E+00	
165	4	10	1	0	7.8	77	55	2	0	1.00E+07	5.50E-06	2.00E-07	0.00E+00	
166	4	10	ckbd	0	7.8	26	26	0	0	9.16E+06	2.84E-06	0.00E+00	0.00E+00	
167	4	25	0	0	7.8	6	6	0	0	9.98E+06	6.01E-07	0.00E+00	0.00E+00	
168	4	25	1	0	7.8	151	131	2	0	1.00E+07	1.31E-05	2.00E-07	0.00E+00	
169	4	25	ckbd	0	7.8	74	74	0	0	9.98E+06	7.41E-06	0.00E+00	0.00E+00	
172	4	1	1	60	15.6	187	97	9	0	1.00E+07	9.70E-06	9.00E-07	0.00E+00	
173	4	1	ckbd	60	15.6	130	130	0	0	9.99E+06	1.30E-05	0.00E+00	0.00E+00	
174	4	10	0	60	15.6	13	13	0	0	9.99E+06	1.30E-06	0.00E+00	0.00E+00	
175	4	10	1	60	15.6	346	236	11	0	1.00E+07	2.36E-05	1.10E-06	0.00E+00	
176	4	10	ckbd	60	15.6	170	170	0	0	9.98E+07	1.70E-06	0.00E+00	0.00E+00	
177	4	25	0	60	15.6	25	25	0	0	9.98E+06	2.51E-06	0.00E+00	0.00E+00	
178	4	25	1	60	15.6	528	509	2	0	1.00E+07	5.09E-05	2.00E-07	0.00E+00	
179	4	25	ckbd	60	15.6	308	308	0	0	1.00E+07	3.08E-05	0.00E+00	0.00E+00	
181	2	1	1	0	7.8	26	6	2	0	1.00E+07	6.00E-07	2.00E-07	0.00E+00	
182	2	2	1	ckbd	0	7.8	18	18	0	0	9.96E+06	1.81E-06	0.00E+00	0.00E+00
183	2	10	0	0	7.8	1	1	0	0	9.96E+06	1.00E-07	0.00E+00	0.00E+00	
184	2	10	1	0	7.8	108	68	4	0	1.00E+07	6.80E-06	4.00E-07	0.00E+00	
185	2	10	ckbd	0	7.8	38	38	0	0	9.97E+06	3.81E-06	0.00E+00	0.00E+00	
186	2	25	0	0	7.8	1	1	0	0	1.00E+07	1.00E-07	0.00E+00	0.00E+00	
187	2	25	1	0	7.8	194	185	1	0	1.00E+07	1.85E-05	1.00E-07	0.00E+00	
188	2	25	ckbd	0	7.8	93	93	0	0	9.99E+06	9.31E-06	0.00E+00	0.00E+00	
189	2	1	0	60	15.6	1	1	0	0	9.99E+06	1.00E-07	0.00E+00	0.00E+00	
191	2	1	1	60	15.6	163	103	6	0	1.00E+07	1.03E-05	6.00E-07	0.00E+00	
192	2	1	ckbd	60	15.6	115	115	0	0	1.00E+07	1.15E-05	0.00E+00	0.00E+00	
193	2	10	0	60	15.6	10	10	0	0	1.00E+07	1.00E-06	0.00E+00	0.00E+00	
194	2	10	1	60	15.6	306	246	6	0	9.98E+06	2.46E-05	6.01E-07	0.00E+00	
195	2	10	ckbd	60	15.6	218	218	0	0	1.00E+07	2.18E-05	0.00E+00	0.00E+00	
196	2	25	0	60	15.6	22	22	0	0	9.99E+06	2.20E-06	0.00E+00	0.00E+00	
197	2	25	1	60	15.6	527	480	5	0	9.99E+06	4.80E-05	5.01E-07	0.00E+00	
198	2	25	ckbd	60	15.6	311	311	0	0	9.98E+06	3.12E-05	0.00E+00	0.00E+00	
199	2	1	1	0	2.8	2	2	0	0	9.99E+06	2.00E-07	0.00E+00	0.00E+00	
201	2	10	1	0	2.8	18	8	1	0	9.94E+06	8.05E-07	1.01E-07	0.00E+00	
202	2	10	ckbd	0	2.8	1	1	0	0	9.98E+06	1.00E-07	0.00E+00	0.00E+00	
204	2	25	1	0	2.8	39	39	0	0	9.98E+06	3.91E-06	0.00E+00	0.00E+00	
205	2	25	ckbd	0	2.8	9	9	0	0	9.98E+06	9.02E-07	0.00E+00	0.00E+00	
206	2	1	1	60	5.6	17	7	1	0	1.00E+07	7.00E-07	1.00E-07	0.00E+00	
207	2	1	ckbd	60	5.6	12	12	0	0	9.98E+06	1.20E-06	0.00E+00	0.00E+00	
209	2	10	1	60	5.6	42	23	2	0	1.00E+07	2.30E-06	2.00E-07	0.00E+00	
210	2	10	ckbd	60	5.6	19	19	0	0	1.00E+07	1.90E-06	0.00E+00	0.00E+00	
211	2	25	0	60	5.6	1	1	0	0	9.98E+06	1.00E-07	0.00E+00	0.00E+00	
212	2	25	1	60	5.6	104	84	2	0	9.98E+06	8.42E-06	2.00E-07	0.00E+00	
213	2	25	ckbd	60	5.6	44	44	0	0	1.00E+07	4.40E-06	0.00E+00	0.00E+00	
215	4	10	0	0	2.8	2	2	0	0	1.00E+07	2.00E-07	0.00E+00	0.00E+00	
216	4	10	1	0	2.8	3	3	0	0	1.00E+07	3.00E-07	0.00E+00	0.00E+00	
217	4	10	1	0	2.8	12	12	0	0	9.96E+06	1.20E-06	0.00E+00	0.00E+00	
218	4	10	ckbd	0	2.8	26	27	0	0	9.96E+06	2.71E-06	0.00E+00	0.00E+00	
220	4	25	1	0	2.8	25	25	0	0	1.00E+07	2.50E-06	0.00E+00	0.00E+00	
221	4	25	ckbd	0	2.8	11	11	0	0	9.95E+06	1.11E-06	0.00E+00	0.00E+00	
222	4	1	1	60	5.6	46	46	0	0	1.00E+07	4.60E-06	0.00E+00	0.00E+00	
223	4	1	ckbd	60	5.6	12	12	0	0	1.00E+07	1.20E-06	0.00E+00	0.00E+00	
224	4	10	0	60	5.6	1	1	0	0	1.00E+07	1.00E-07	0.00E+00	0.00E+00	
225	4	10	1	60	5.6	40	40	0	0	1.00E+07	4.00E-06	0.00E+00	0.00E+00	
226	4	10	ckbd	60	5.6	17	17	0	0	9.99E+06	1.70E-07	0.00E+00	0.00E+00	
228	4	25	1	60	5.6	119	79	4	0	9.96E+06	7.93E-06	4.02E-07	0.00E+00	
229	4	25	ckbd	60	5.6	38	38	0	0	1.00E+07	3.80E-06	0.00E+00	0.00E+00	
230	4	1	0	60	106.2	187	132	17	0	1.00E+07	1.32E-05	1.70E-06	0.00E+00	
234	4	10	1	60	106.2	3462	3223	48	0	9.99E+06	3.23E-04	4.80E-06	0.00E+00	
236	3	1	0	0	53.1	34	30	2	0	1.00E+07	3.00E-06	2.00E-07	0.00E+00	
241	3	1	1	0	53.1				1	9.53E+06		0.00E+00	1.05E-07	
242	2	1	0	0	28.8	3	3	0	0	1.00E+07	3.00E-07	0.00E+00	0.00E+00	
244	2	1	ckbd	0	28.8	341	341	0	0	1.00E+07	3.41E-05	0.00E+00	0.00E+00	
245	2	10	0	0	28.8	22	22	0	0	9.95E+06	2.21E-06	0.00E+00	0.00E+00	
247	2	10	ckbd	0	28.8	480	480	0	0	9.99E+06	4.80E-05	0.00E+00	0.00E+00	
248	2	25	0	0	28.8	64	60	2	0	9.98E+06	6.01E-06	2.00E-07	0.00E+00	
250	2	25	ckbd	0	28.8	1102	1100	1	0	1.00E+07	1.10E-04	1.00E-07	0.00E+00	
251	2	1	0	60	57.6	27	27	0	0	9.95E+06	2.71E-06	0.00E+00	0.00E+00	
252	2	1	1	60	57.6				1	9.50E+06		0.00E+00	1.05E-07	
253	1	1	0	45	40.7	23	14	1	0	1.00E+07	1.40E-06	1.00E-07	0.00E+00	
254	1	1	1	45	40.7	865	605	26	0	1.00E+07	6.05E-05	2.60E-06	0.00E+00	
255	1	1	ckbd	45	40.7	541	541	0	0	1.00E+07	5.41E-05	0.00E+00	0.00E+00	
256	1	10	0	45	40.7	38	38	0	0	1.00E+07	3.80E-06	0.00E+00	0.00E+00	
257	1	10	1	45	40.7	1665	1447	22	0	9.99E+06	1.45E-04	2.20E-06	0.00E+00	
258	1	10	ckbd	45	40.7	912	901	2	0	1.00E+07	9.01E-05	2.00E-07	0.00E+00	
259	1	25	0	45	40.7	101	93	4	0	9.99E+06	9.31E-06	4.00E-07	0.00E+00	
260	1	25	1	45	40.7	2868	2537	40	0	1.00E+07	2.54E-04	4.00E-06	0.00E+00	
261	1	25	ckbd	45	40.7	1711	1696	6	0	1.00E+07	1.70E-04	6.00E-07	0.00E+00	